

ROTARY REHABILITATION APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates generally to the field of exercise and rehabilitation, and more specifically, to an apparatus providing selective adjustment of the range of motion of a user's extremities, including either arms and legs, actively engaging in or passively participating in a cycling action.

2. Description of the Related Art

[0002] One of the most significant and the most common athletic injuries is to the knee, and published data continues to report at an incidence of between one-quarter and one-third of all men and women experience some type of knee injury annually. Approximately 10.8 million individuals visit a physician for knee injuries alone each year. Total estimated annual U.S. costs of all musculoskeletal conditions is \$254 billion. Many injuries to the lower extremities of persons necessitate the use of rehabilitation exercises. Such injuries may include those to the joints of a person's leg (e.g., knee, hip), replacement of one's joint (e.g., total hip or knee arthroplasty [THA, TKA]), ligaments or tendons associated with these joints (e.g., anterior cruciate or medial collateral ligament [ACL, MCL], or patella or quadriceps tendons), or muscles of the leg (e.g., Rectus or biceps femoris, etc). Rehabilitation exercises are also frequently prescribed after surgery has been performed to further repair an injured site on a user's extremity.

[0003] Major trunk injuries are also exceedingly common in the United States. Major trunk injuries include those injuries that affect the shoulders and back. The shoulder joint, being the most flexible joint in the human body, can be easily injured because of accidentally over-extending the range of motion. The U.S. Department of Labor estimates that thirty-five percent of all musculoskeletal injuries are major trunk injuries. Over four million visits are made to health care professionals each year because of shoulder injuries. Moreover, the U.S. Department

of Labor estimates that the average time off-work for shoulder injuries is twelve days. This corresponds to an estimated \$13-20 billion due to time lost from work.

[0004] One common rehabilitation exercise recommended to improve muscle, ligament and tendon strength, and endurance for extremities post-injury or post-surgically, is movement in a cycling motion. The movement of a person's upper or lower extremity in a circular path induces motion in the articulations that form the shoulder and elbow or hip and knee, respectively. However, for rehabilitation to be effective, it must be tailored to the specific needs of a given person based on their physical size, type of injury, and plan for recovery, among other factors. For example, if a surgical repair has been made to a torn ACL of a person's leg, it is often desirable at the beginning of a rehabilitation regimen to limit the flexion or extension of the knee, due not only to pain, but also to avoid damage to the repair. Likewise, for the shoulder, a physician may recommend limiting the motion of the shoulder to something far less than its full capability of 360 degrees until natural recovery and sufficient rehabilitation has occurred. Although cycle-type exercise machines are recommended for use in certain rehabilitation regimens, they generally do not facilitate the adjustment of the range of motion of one individual extremity. Further, these machines are limited to the standard pedal or handle arrangement where one lever (handle or pedal) is offset from the other by 180 degrees around a hub. There are, however, rehabilitation regimens where benefits to flexibility, strength, and/or endurance are achieved by offsetting levers or handles at another angles for passive, assisted active, and active range of motion.

SUMMARY OF THE INVENTION

[0005] A rotary rehabilitation apparatus is presented that allows for the selection of a range of motion for upper and/or lower extremities of a person engaging in a cycling action. The adjustable lever assembly allows for safer, more immediate rehabilitation following hip, knee, shoulder, and/or elbow injuries and further provides for pain reduction, increasing the range of motion, strengthening soft tissue and general conditioning. The assembly comprises one movable lever and a flywheel rotatably mounted on a support and having a series of bores along a diameter thereof with which the movable lever or handle is releasably mounted. In an exemplary

arrangement where the rotary rehabilitation apparatus is incorporated with cycle-type exercise machine, for example a cycle ergometer, a user will sit on the seat and place their feet or hands on the levers to impart a force thereon. As the user's feet or hands move in a circular path, the extremities engage in extension and flexion to cause movement in the articulations formed at the user's hip and knee or shoulder and elbow joints. The amount of movement in the articulations of the extremity and consequently, the range of motion at these joints can be controlled by mounting the lever with the appropriate bore on the flywheel. If increased extension and flexion is desired, the lever can be mounted with a bore further away from the axis of rotation of the flywheel. Conversely, if a smaller degree of extension and flexion is preferred, the lever can be mounted with a bore closer to the flywheel axis of rotation.

[0006] In one configuration, the moveable lever is releasably mounted with a mounting bore of the flywheel and the other lever is left at full diameter. This configuration allows an adjustable range of motion for one extremity and a fixed range of motion for the other extremity, which allows for more limited, rehabilitative exercises for one extremity (e.g., an injured knee or shoulder) and more robust exercises for the other.

[0007] In another aspect, more than one series of bores extend across different diameters of the flywheel, so that the movable lever can be mounted at various angles with respect to the fixed lever around the axis of rotation. For example, while levers are typically aligned 180 degrees from one another around a hub on an cycle-type exercise machine, it may be desired in rehabilitation regimens to position the levers at a different angle to work on the passive range of motion ("PROM"), the assisted active range of motion ("AAROM"), and the active range of motion ("AROM").

[0008] The rotary rehabilitation apparatus of the present invention provides improved options for rehabilitation regimes where a cycling or rotary action would be beneficial to recovery from injury of a person's extremities. As a user progresses in their injury recovery, such as by increasing strength and flexibility in their extremities, the movable lever or handle can be disengaged and remounted within another bore that provides a different range of motion for their extremity when rotating the assembly.

[0009] By rapidly affecting PROM, AAROM and AROM this invention will reduce the time required to recover from extremity injuries, increasing improvements in measurable outcomes such as range of motion, edema, proprioception, return to unassisted gait activities, initial functional independent measures, strength and conditioning; reduce overall inpatient and outpatient costs, accelerate return to vocational or avocational activities; and significantly improve quality of life by expediting a return to autonomy.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIGS. 1A-1D show various views (right side elevation view, perspective view, top plan view and front elevation view) of the rotary rehabilitation apparatus of the present invention incorporated with a cycle-type exercise machine;

[0011] FIG. 2A is a left perspective view of the flywheel mounted with the hub; FIG. 2B is a right perspective view of the flywheel of FIG. 2A; FIG. 2C is an exploded view of the flywheel as mounted with the hub; FIG. 2D is a front elevation view of the flywheel of FIG. 2A; FIG. 2E is a right side elevation view of the flywheel;

[0012] FIG. 3A is a perspective view of the pedal lever assembly; FIG. 3B is an exploded view of the pedal lever assembly; FIG. 3C is a top plan view of the pedal lever assembly; FIG. 3D is a front elevation view of the pedal lever assembly; FIG. 3E is a right side elevation view of the pedal lever assembly;

[0013] FIG. 4A is a left perspective view of the rotary rehabilitation apparatus showing one lever approaching engagement with one of the bores of the flywheel and the flywheel rotatably mounted with a hub; FIG. 4B is a right perspective view of the rotary rehabilitation apparatus showing the lever mounted with the flywheel and the hub with which the flywheel is mounted; FIG. 4C is a top view of the rotary rehabilitation apparatus showing the lever mounted with the flywheel, and the flywheel mounted with the hub; FIG. 4D is a front elevation view of the rotary rehabilitation apparatus of FIG. 4C; FIG. 4E is a right side elevation view of the rotary rehabilitation apparatus of FIG. 4C;

[0014] FIG. 5A is a side elevation view of one embodiment of the disk of the flywheel showing bores along two diameters thereof; FIG. 5B is a side elevation

view of another embodiment of the disk of the flywheel showing bores along four diameters thereof; FIG. 5C is a side elevation view of one brace member of the flywheel; FIG. 5D is a front elevation view of the brace member of FIG. 5C; FIG. 5E is a rear elevation view of the coupling for mounting the hub with the flywheel; FIG. 5F is a side elevation view of the coupling of FIG. 5E; FIG. 5G is a front elevation view of the coupling of FIG. 5E;

[0015] FIGS. 6A and 6B schematically show leg members having feet positioned on the levers of the rotary rehabilitation apparatus at a first position of rotation and at a second position of rotation; and

[0016] FIGS. 7A and 7B schematically show leg members having feet positioned on the levers of the rotary rehabilitation apparatus with one of the levers mounted at a different position on the flywheel than the levers of FIGS. 6A and 6B and the levers being at a first position of rotation and at a second position of rotation;

[0017] FIG. 8 is a right side elevation view of a rotary rehabilitation apparatus configured for upper extremity movement of the shoulder and/or elbow; and

[0018] FIGS. 9A-9E show various views (perspective view, exploded perspective view, right side elevation view, top plan view and front elevation view) of the lever assembly of a rotary rehabilitation apparatus of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0019] One rotary rehabilitation apparatus 10 providing for the selection of a range of motion for one or both legs 200 of a person is shown in Figs. 1A-1D. An embodiment of the rotary rehabilitation apparatus for rehabilitating a person's upper extremities will be discussed in detail below. The rotary rehabilitation apparatus 10 is shown incorporated in a cycle-type exercise machine 100 having a support 102 upon which the apparatus 10 is rotatably mounted and a seat 104 positioned at a distance from the support 102. In this arrangement, the person can sit in the seat 104, place their feet 204 on the levers 12a and 12b and impart a pushing force thereto with their legs 200 to rotate a flywheel 14 at a center point 15 thereof around an axis extending in the horizontal plane.

[0020] The adjustable range of motion for each leg 200 is achieved by having the movable lever 12a be repositionable along one or more diameters of the flywheel 14. The flywheel 14 has a series of bores 16 extending laterally therethrough parallel to the flywheel rotational axis and formed in a row along the flywheel diameter so that the lever 12a can be removably mounted with one of the bores 16. In the embodiment of the rotary rehabilitation apparatus 10 shown in FIGS. 1A-1D, the flywheel 14 has two separate series of bores 16 each aligned along one flywheel diameter and orthogonal to one another. As can also be seen, the movable lever 12a is mounted with the flywheel 14 and the fixed lever 12b is mounted with a crank 18 extending radially from a hub 20 with which the flywheel 14 is rotatably mounted at the center point 15. This configuration allows for lever adjustment both along the flywheel 14 diameter towards or away from the center point 15, and concentrically on the flywheel 14 around the center point 15 such that the lever 12a may be at an offset angle relative to the fixed lever 12b about the flywheel axis of rotation of 90, 180 or 270 degrees.

[0021] Figs. 2A-2E show more detail of the flywheel 14 and mounting with the hub 20. The flywheel 14 comprises a circular disk 22 having opposing first and second planar surfaces 24, 26 and a perimeter edge 28, and a circumferential ring 30 fixed around the perimeter edge 28. The ring 30 may be press fit onto the disk perimeter edge 28 or may be mounted thereto with fasteners or adhesives. A first set of notches 32 are formed along an inner edge 34 of the ring 30 adjacent to the disk first planar surface 24 and in alignment with each row of the series of bores 16. These notches 32 facilitate the extension of brace members 36 across the disk planar surface 26 on a diameter of the ring 30 to matingly fit with the notches 32. A second set of notches 38 having a curved profile are formed along the ring inner edge 34 adjacent to the disk second planar surface 26. When the movable lever 12a is mounted with the bore 16 furthest from the center point 15, the notches 38 provide extra clearance such that the lever 12 fits properly adjacent to the second planar surface 26.

[0022] Depending on the functionality desired in the cycle-type exercise machine 100, the flywheel 14 can be designed to have a relatively large or small moment of inertia. A large moment of inertia flywheel 14 requires more peddling force to accelerate the same to a given speed, but also causes the flywheel 14 to better

resist changes in speed, resulting in smoother “steady-state” cycling, which may be preferred in certain rehabilitation exercises. The higher moment of inertia is created by making the flywheel 14 heavier and/or moving more of the flywheel weight out to the circumferential ring 30.

[0023] The flywheel 14 is mounted with the hub 20 by insertion of a fastener 39 through the bore 16 of the disk 22 forming the center point 15 of the flywheel 14 and through a coupling 40 for securing with the hub 20. Specifically, the fastener 39 extends into a receiving bore 42 formed in a stem 44 rotatably mounted within a body 46 of the hub 20. In this arrangement, the hub body 46 is stationary on the support 102 while the hub stem and the mounted flywheel 14 rotate relative to the hub body 46. The hub 20 is preferably mounted adjacent to the first planar surface 24 on a side of the flywheel 14 opposite of the movable lever 12a.

[0024] In addition to controlling the moment of inertia in the flywheel 14, the overall resistance to turning of the flywheel 14 may be controlled to increase the amount of work a user must perform in peddling, as those of skill in the art appreciate with respect to known cycle-type exercise machines. For example, frictional resistance may be incorporated in to the design of the hub 20, such that the rotation of the stem 44 relative to the hub body 46 requires a certain amount of force to overcome the static and dynamic friction within the hub 20. Alternatively, a frictional surface (not shown), for example, a brake, may selectively engage the circumferential ring 30 to create static and dynamic friction.

[0025] Figs. 3A-3E show the components of the movable lever 12a. The lever body 48 has opposing surfaces 49 onto which the user’s foot is placed and a bore 50 extending through the body 48 from a lateral side face 52 to a medial side face 54. A chamfer 56 is also formed at the bore entrance of the lateral side face 52. A sleeve 58 has a first end 60 and a second end 62, and is configured for insertion into the bore 50 such that the second end 62 extends out of the lever medial side face 54. A pin 64 is inserted into the sleeve 58 and has a shank 66 extending out of second end 62 thereof, and a collar 68 having a concentric base 70 configured to abut the first end 60 and a beveled region 72 mateably fitting within the chamfer 56. A protrusion 74 is formed on the shank 66 near an end distal to the collar 68 such that the pin 64 frictionally fits within one bore 16 of the flywheel 14 to secure the lever body 48

thereto. If enough of a pulling force is applied to the lever body 48 away from the flywheel 14, the protrusion 74 is removed from the frictional fit in the bore 16 and may be repositioned as desired in another bore 16. The lever body 48 and sleeve 58 are also rotatable about the pin 64 such that as the flywheel 14 rotates, one of the peddling surfaces 49 is maintained in alignment such that the user can continue to apply a force thereto with their feet 204 through the cycling motion.

[0026] Figs. 4A-4E show an exemplary orientation for the rotary rehabilitation apparatus 10 where the movable lever 12a is shown mounting with one of the radially outermost bores 16 of the flywheel 14. In Fig. 5A, the embodiment of the flywheel 14 of Figs. 1A-1D having two series of bores 16 is shown. Each concentric dotted line on the flywheel disk 22 connecting bores 16 on different rows represents a certain distance from the center point 15 (i.e., point of rotation) of the flywheel 14, for example, one inch. Thus, one can quickly determine the degree of adjustment achieved by mounting a movable lever 12a with one particular bore 16. Fig. 5B shows another flywheel 14 embodiment having four series of bores 16 with each row rotated 45 degrees with respect to one another. This arrangement allows for more fine-tuning of the angle offset between the movable lever 12a and the fixed lever 12b, which may be desired in certain rehabilitation regimens. Figs. 5C and 5D show one brace member 36 having a curved edge 76 for abutting the coupling 40 on an end opposite of the notches 32 of the circumferential ring 30, and beveled edges 78 on either side of the curved edges 76. Each beveled edge 78 of one brace member 36 abuts a beveled edge 78 of another brace member 36 extending along an adjacent row of the series of bores 16. Figs. 5E-5G also show the coupler 40 in detail. A cavity 80 is formed in the cylindrical coupler 40 and is shaped to receive the stem 44 of the hub 20. A bore extends from the cavity through the coupler 40 with a diameter sufficient to allow the fastener 38 to extend therethrough to reach the stem 44. In this way, the coupler 40 provides the interface to more securely mount the flywheel 14 for rotation about the hub body 46.

[0027] The motion of a person's legs 200 utilizing the rotary rehabilitation apparatus 10 of the present invention is simulated in Figs. 6A-7B showing the hip joint 206, the upper leg 208 (e.g., the femur), the knee joint 210 and the lower leg 212 (e.g., the tibia). In Figs. 6A and 6B, the fixed lever 12b is at a radial distance (e.g., 6

inches) from the flywheel 14 axis of rotation that is much greater than the radial distance of the movable lever 12a (e.g., 1 inch) from such axis of rotation. This provides a relatively large range of motion for the user's leg peddling the fixed lever 12b while providing a relatively small range of motion for the leg rotating the movable lever 12a. In this configuration, the movable lever 12a limits the change in angle formed between the lower leg 212 and a tangent extension of the upper leg 208 to 11 degrees, with the angles remaining between 67 degrees and 56 degrees.

[0028] This rehabilitation regimen may be recommended when the user is not to bend their leg to a certain degree, for example, to limit stresses on the hip 206 or knee 210. Conversely, in Figs. 7A and 7B, the movable lever 12a and fixed lever 12b are at the same radial distance (e.g., 6 inches) from the flywheel 14 axis of rotation. Thus, both of the user's legs will participate in a large range of motion when peddling with the apparatus 10. The movable lever 12a, in the embodiment of Figs. 7A and 7B, allows for the angle formed between the lower leg 212 and a tangent extension of the upper leg 208 to cycle between 6 degrees and 88 degrees. This large range of motion rehabilitation regimen brings about much more flexion and extension than the embodiment of Figs. 6A and 6B, and consequently more movement of the hip and knee articulations. Thus, the embodiment of Figs. 7A and 7B may be preferred during a later stage of injury or post-surgery rehabilitation when the flexibility and strength of the affected joint, for example, a user's ACL or total knee arthroplasty (TKA) has increased.

[0029] In the embodiment of the rotary rehabilitation apparatus 218 shown in FIG. 8, for upper extremities including the shoulder, wrist and elbow, the adjustable range of motion for each arm 220 is achieved by having the movable hand lever 222 be repositionable along one or more diameters of the flywheel 224. The flywheel 224 has a series of bores 226 extending laterally therethrough parallel to the flywheel rotational axis and formed in a row along the flywheel diameter so that the hand lever 222 can be removably mounted with one of the bores 226. In the embodiment of the rotary rehabilitation apparatus 218 shown in FIG. 8, the flywheel 224 has two separate series of bores 226 each aligned along one flywheel diameter and orthogonal to one another. Not shown in FIG. 8, but comparably configured as in FIGS. 1A-1D, is a fixed hand lever on the opposite side of the flywheel 224 mounted

to a crank extending radially from a hub with which the flywheel 224 is rotatably mounted at the center point 228. This configuration allows for lever adjustment both along the flywheel 224 diameter towards or away from the center point 228, and concentrically on the flywheel 224 around the center point 228 such that the hand lever 222 may be at an offset angle relative to the fixed hand lever about the flywheel axis of rotation of 90, 180 or 270 degrees.

[0030] Figs. 9A-9E show the components of the movable hand lever 222. The hand lever body 248 may be tubular in shape or have other configurations that readily accommodate gripping by the human hand. The hand lever has a bore 250 extending through the body 248 from a lateral side face 252 to a medial side face 254. A chamfer 256 is also formed at the bore entrance of the lateral side face 252. A sleeve 258 has a first end 260 and a second end 262, and is configured for insertion into the bore 250 such that the second end 262 extends out of the lever medial side face 254. A pin 264 is inserted into the sleeve 258 and has a shank 266 extending out of second end 262 thereof, and a collar 268 having a concentric base 270 configured to abut the first end 260 and a beveled region 272 mateably fitting within the chamfer 256. A protrusion 274 is formed on the shank 266 near an end distal to the collar 268 such that the pin 264 frictionally fits within one bore 226 of the flywheel 224 to secure the hand lever body 248 thereto. If enough of a pulling force is applied to the hand lever body 248 away from the flywheel 224, the protrusion 274 is removed from the frictional fit in the bore 226 and may be repositioned as desired in another bore 226. The lever body 248 and sleeve 258 are also rotatable about the pin 264 such that as the flywheel 224 rotates, the lever body and sleeve also rotate such that the user can continue to apply a force thereto with their hands and arms through the rotary motion.